

New Event Generator Review

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38. Monte Carlo Event Generators 405

38. MONTE CARLO EVENT GENERATORS

Written January 2012 by P. Nason (INFN, Milan) and P.Z. Skands (CERN).

General-purpose Monte Carlo (GPMC) generators like **HERWIG** [1], **HERWIG++** [2], **PYTHIA 6** [3], **PYTHIA 8** [4], and **SHERPA** [5], provide fully exclusive modeling of high-energy collisions. They play an essential role in QCD modeling (in particular for aspects beyond fixed-order perturbative QCD), in data analysis, where they are used together with detector simulation to provide a realistic estimate of the detector response to collision events, and in the planning of new experiments, where they are used to estimate signals and backgrounds in high-energy processes. They are built from several components, that describe the physics starting from very short distance scales, up to the typical scale of hadron formation and decay. Since QCD is weakly interacting at short distances (below a femtometer), the components of the GPMC dealing with short-distance physics are based upon perturbation theory. At larger distances, all soft hadronic phenomena, like hadronization and the formation of the underlying event, cannot be computed from first principles, and one must rely upon QCD-inspired models.

order the clusterings. However, strong ordering in energy times angle, in virtuality or in transverse momenta are in fact equivalent in the dominant region. In fact, in the small-angle limit, the virtuality t of a parton of energy E , splitting into two on-shell partons is given by

$$t = E^2 z(1-z)(1-\cos\theta) \approx \frac{z(1-z)}{2} E^2 \theta^2, \quad (38.1)$$

where z and $1-z$ are the energy fractions carried by the produced partons, and θ is their relative angle. The transverse momentum of the final partons relative to the direction of the incoming one is given by

$$p_T^2 \approx z^2(1-z)^2 E^2 \theta^2. \quad (38.2)$$

Thus, significant differences between these measures only arise in regions with very small z or $1-z$ values. In QCD, because of soft divergences, these regions are in fact important, and the choice of the appropriate ordering variable is very relevant (see Sec. 38.3).

The so called KLN theorem [6,7] guarantees that large logarithmi-

- **New review in RPP 2012**
 - Originally suggested by Advisory Committee (thank you!)
 - 10 pages (in big book)
- **Written by**
 - Paolo Nason (INFN), one of the main POWHEG authors
 - Peter Skands (CERN), one of the main PYTHIA authors
 - Coordinated by Christian Bauer (LBNL)
- **Very active field**
 - Particularly since start of LHC
 - Lots of interaction between theory and LHC experiments
 - Might be useful to cover some of the latest developments (e.g. matrix element matching), but this would require more space

- **Discusses “general-purpose Monte Carlo” (GPMC) generators**
 - HERWIG(++), PYTHIA 6 & 8, SHERPA, ...
- **4 main sections**
 - **Short-distance physics in GPMC generators**
 - Basic concepts for simulation of dominant QCD processes
 - **Hadronization models**
 - Discusses both string and cluster models
 - Decay of primary hadrons into stable ones
 - **Models for soft hadron-hadron physics**
 - Underlying event, minimum bias interactions
 - **Parameters and tuning**
 - Brief discussion of MC tuning, including automated tools

- **Not covered in this review article**
- **New neutrino event generators review in preparation**
 - Two new authors:
 - Hugh Gallagher (Tufts)
 - Yoshinari Hayato (Tokyo)
 - Coordinated by Cheng-Ju Lin (LBNL)
 - Work is in progress, but draft was not ready in time for RPP 2012
 - Will be included in the 2013 review updates